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Detection And Treatment Of Hemorrhage In The Postoperative Patient

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Hemorrhage is a devastating event that can occur in the perioperative period. It is estimated that 2.35 in 1000 patients will experience hemorrhage associate with surgery.[1]Adverse outcomes affecting patient morbidity, mortality and quality of life are associated with hemorrhage.[2] Timely detection, diagnosis and appropriate intervention in the setting of hemorrhage are imperative to reduce adverse outcomes of shock such as end organ damage, chronic disability or death. Anesthesia practitioners hold the charge of monitoring and managing the patient's hemodynamic status and play an integral role in the detection and management of the hemorrhaging patient.

Case Report

A 71 year old male with hypertension, COPD and kidney disease presented with a large renal mass for laparoscopic/possible open nephrectomy. Medications included lisinopril, rouvastatin, aspirin. Preoperative labs revealed hemoglobin 14 gm/dL, hematocrit 41% creatinine 0.89 mg/dL. 2 mg versed given and patient was brought to the OR. Blood pressure, ECG and Sp02 monitors applied. Placement of epidural (ED) catheter and arterial line performed. ED catheter dosed with 5 ml 0.25% ropivicaine 50 mcg fentanyl. Phenylephrine drip was initiated 10 mcg/kg/min stabilizing arterial blood pressure (ABP). Induction of anesthesia proceeded with 50 mcg fentanyl 160 mg propofol 8 mg vecuronium. Direct laryngoscopy performed and trachea intubated. Respirations controlled with mechanical ventilation and warmed IV fluid and convection heating initiated. Anesthesia was maintained with 3% inspired concentration in a mixture of 1L/min oxygen and 1L/min air. Phenylephrine drip was titrated to achieve mean arterial pressure of 70 mm/Hg. Fluid intake, blood loss and urine output (UO) closely monitored. Conversion to open procedure was necessary due to bleeding obscuring the surgical field. 600 ml blood loss was appreciated and crystalloid bolus delivered. Removal of kidney was achieved. Neuromuscular blockade antagonized and 5 ml 0.25% ropivicaine 50 mcg fentanyl via ED catheter was delivered. During emergence from anesthesia ABP decreased to 77/50 mmHg; phenylephrine increased to 40 mcg/min achieving adequate ABP. Awake extubation performed without incident. Shortly after arrival to PACU level of consciousness (LOC) and ABP decreased. A crystalloid bolus was delivered and phenylephrine drip increased. H&H drawn; resulted 7.5/25%. Two units PRBC's delivered; H&H post-transfusion 7.1/23%. Surgeon and anesthesia team consulted about patient status. Assessment of drain output, inspection of abdomen, back and incision performed with nothing abnormal noted. Patient was obtunded with periods of intermittent arousal. Two units FFP and two units PRBC's delivered. 20 U vasopressin titrated intravenously to support ABP. Crystalloid resuscitation continued and 25 gm albumin delivered. Oliguria, diaphoresis, persistent hypotension and mild tachycardia noted

with waxy skin tone. Phenylephrine increased 250 mcg/min and epinephrine drip initiated with no significant improvement. Calcium gluconate administered. ABG was drawn and resulted- pH 7.1 and a base excess of -23. Emergent intubation of trachea and initiation of mechanical ventilation performed. Return to the operating room for exploration revealed a liver laceration and 2.5 liters of blood was evacuated from the abdomen. In total 10 units PRBC's and 6 units FFP were infused. Patient admitted to ICU intubated and unconscious on vasopressor support with phenylephrine and epinephrine. Postoperative ABG revealed severe metabolic acidosis. Post-operative day one patient was unresponsive, anuric, creatinine 2.3mg/dL and in liver shock requiring evacuation by helicopter for tertiary care. Patient returned to the VA hospital a week later, alert and oriented and was admitted to medical floor. At tertiary facility hemodialysis was performed for acute renal failure. The patient's creatinine levels remained > 5.0 mg/dL and hemodialysis continuation was necessary. Liver enzymes returned to normal and plan for inpatient rehabilitation was planned due to extreme physical deconditioning.

Discussion

This case demonstrates the importance of timely and efficient intervention in the setting of ensuing symptoms of shock in the postoperative setting. The cardinal findings seen in the shock continuum include hypotension, oliguria, altered mental status, metabolic acidosis, and cool clammy skin.[3] When hemorrhage is not overt the anesthesia practitioner must have a comprehensive knowledge base in order to detect and treat shock when symptoms arise in order to avoid deleterious consequences.

Many factors can contribute to postoperative hypotension. If bleeding is occult then judicious review of potential contributors needs to be explored. In this case, total estimated blood loss was approximately 750 ml; an allowable blood loss of 1500 ml was calculated preoperatively. The patient received 5300 ml of crystalloid fluid intra-operatively and urine output was calculated at 470 ml. Post-operative fluid deficit was not determined an obvious cause of hypotension and shock symptoms. Neuraxial anesthesia and repeat epidural dosing of local anesthetic and opioid at the end of the case was considered to be of etiological significance as a potential cause for hypotension and resultant hypoxemia. Timing, dosing and duration of action of the local anesthetic was reviewed and the patient's motor function was assessed. It was determined that the epidural was not likely to be a causative factor of the hemodynamic instability.

Treatment of shock should never be delayed during once it is suspected and possible hemorrhage should be considered. Crystalloid resuscitation due to its ability to rapidly expand plasma volume and reverse hypotension continues to be the first line treatment for shock and with suspected hemorrhage.[4] The patient was bolused two liters of crystalloid followed by continuous delivery of lactated Ringer's solution. Current studies suggest that there is no clear advantage to use of colloid based fluids compared to crystalloid solution during fluid resuscitation in the setting of shock, although some findings reveal an advantage when colloids are delivered concurrently.[5,6] Albumin was delivered in this case to procure the possible advantage associated with addition of intravascular colloids.

Vasopressors are recommended in the treatment of shock if initial fluid bolus does not correct hemodynamics.[7] Phenylephrine was delivered throughout the resuscitation process and

vasopressin and epinephrine were added when limited response was noted with phenylephrine alone.

Concurrent with fluid resuscitation, assessment of pertinent lab values should be performed. Hemoglobin and hematocrit (H&H) levels were drawn and revealed decreased values suggestive of acute blood loss when compared to preoperative labs. Blood transfusion was initiated and repeating the H&H helped guide the need for subsequent blood transfusions.

Unfortunately, a serum lactate was never obtained and could have offered information early on in the process. The ability to clear lactate and normalize lactate levels is reflective of the severity of the shock state; if lactate clearance does not normalize post resuscitation this should instigate suspicion of occult bleeding.[8] Arterial blood gas analysis (ABG) was performed but it was drawn well after symptoms were apparent and when the patient status was declining. Earlier obtainment and trending of ABG's could have instigated earlier intubation and treatment the developing metabolic acidosis. No coagulation studies were obtained.

Maintenance of body temperature above 35°C decreases the affinity for oxygen to bind to hemoglobin and tissue oxygenation.[8] Hypothermia instigates coagulopathies and alterations in glucose handling thereby increasing bleeding and altering metabolic processes.[8] Although the blood products were warmed upon delivery, convection warming and warming of IV fluids was not performed. Also, temperature monitoring was sporadic and patient was found to be hypothermic upon intermittent assessment.

In retrospection, there was immediate awareness of a shock state occurring in the patient and many imperative interventions were initiated in a timely manner. Key components such as immediate fluid resuscitation and stepwise vasopressor initiation were performed. Critique of the process would include failure to obtain important lab values such as serum lactate, coagulation panel and early obtainment of an ABG analysis that may have resulted in decreased metabolic derangement, decreased end organ failure and earlier intubation. The patient suffered severe hypo-perfusion of the liver and kidney during the resuscitative process resulting in persistent renal failure and the need for ongoing hemodialysis. More aggressive warming measures should have been applied to maintain an adequate internal body temperature and support improved tissue perfusion.

Ultimately, accurate discernment that a hemorrhage was the cause of shock and return to operating room for exploration and repair of the laceration of the liver allowed for the survival of the patient. In the future, an algorithm of care in the form of a cognitive visual aid that helps to guide practitioners in the delivery of all key components of shock resuscitation while discerning the etiology of postoperative shock would help to minimize unfavorable consequences.

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Identification, Treatment and Management of Shock in the Surgical Patient

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Abstract

Shock is an adverse physiological occurrence that is life threatening and is associated with high morbidity and mortality for those affected. In the perioperative period many factors are present that challenge the maintenance of homeostasis and can facilitate a shock state in the patient. Anesthesia providers are responsible for assessing, monitoring and maintaining cardiovascular and physiologic stability. High risk surgeries with potential for increased blood loss, long duration operations, fluid losses and the types of procedures, the patients age and current state of health are just a few variables that place the patient at risk of shock. At the head of the bed the anesthetist is the sole provider who holds the primary role in detection, intervention, and treatment of shock as it ensues. Knowledge of the types and stages of shock and an awareness of current best practices regarding how to detect, support and treat shock will provide the best outcomes for the patient.

Identification, Treatment and Management of Shock in the Surgical Patient

Shock

Shock is defined as a state of significantly reduced systemic tissue perfusion causing decreased oxygen delivery to body tissues leading to an imbalance between oxygen delivery and oxygen consumption (Gaieski, 2015). Predicting that shock may be ensuing and having it high on a diagnostic differential for the patient is imperative due to the deleterious sequelae of events and adverse outcomes associated with hypoperfusion that occurs in the shock state. Prolonged states of oxygen deprivation results in derangement of cellular function manifesting as cell membrane ion pump dysfunction, intracellular edema, leaking of intracellular contents and alterations in ability to regulate intracellular pH. Without intervention systemic effects ensue characterized by alterations of serum pH, endothelial dysfunction and stimulation of inflammatory processes in the body. Shock states are initially reversible but if left untreated can develop into an irreversible process involving cell death, end organ damage, multi organ system failure and death (Gaieski, 2015).

Categories of Shock

Shock is categorized into three primary types: hypovolemic, cardiogenic and distributive. Each type can be differentiated by cardiac output and by systemic vascular resistance states. More than one type of shock can be experienced at one time, for instance, cardiogenic shock can develop concurrently with hypovolemic shock.

Hypovolemic shock occurs as a result of decreased cardiac preload due to intravascular volume loss and is primarily induced by either acute or occult blood loss or inadequate fluid replacement peri-operatively. Cardiac output decreases along with the decreased preload and systemic vascular resistance increases in a compensatory effort to continue adequate perfusion to

vital organs (Dutton, 2007). In hemorrhagic shock, stasis of bleeding is the most important and definitive treatment.

Cardiogenic shock is a consequence of cardiac pump failure, which decreases cardiac output (CO). Systemic vascular resistance then increases in an effort to compensate for the diminished CO to maintain perfusion. Common categories of cardiogenic shock etiology include myopathic, arrhythmic, mechanical, or extracardiac, sometimes called obstructive shock. Moypathic cardiogenic shock can be caused by myocardial infarction (especially when greater than 40% of the ventricular wall is involved), dilated cardiomyopathies, stunned myocardium following prolonged ischemia and myocarditis (Gaieski, 2015). Arrhythmic born cardiogenic shock can be induced by both atrial and ventricular arrhythmias (Gaieski, 2015). Mechanical causes of cardiogenic shock include valvular and septal defects or ruptures, ruptured ventricular wall aneurysms, critical aortic stenosis or dissection of ascending aortic aneurysm (Gaieski, 2015). Etiological examples of obstructive shock include massive pulmonary emboli, cardiac tamponade, tension pneumothorax and severe constrictive pericarditis (Gaieski, 2015).

Conversely, distributive or vasodilatory shock is a consequence of severely decreased systemic vascular resistance and cardiac output is typically increased in an effort to compensate for the diminished systemic vascular resistance. Some causes of distributive shock are sepsis, systemic inflammatory response syndrome seen with pancreatitis, burns and multiple trauma situations, anaphylaxis, neurogenic shock, myxedema coma, and post myocardial infarction inflammation (Gaieski, 2015).

Stages of Shock

Anesthesia providers must have a strong understanding of the shock continuum in order to detect, diagnose, support and treat the patient effectively. There are multiple staging

frameworks for shock identifying anywhere from three to six stages in the continuum. Comprehensively there are four primary stages of shock: initial, compensatory, progressive and refractory (Tintinalli, 2010). The stages are differentiated by the severity of circulatory compromise and they are progressive, complex and can overlap (Gaieski, 2015).

The initial stage is associated with up to 15% blood volume loss; approximately 750 ml. In this stage hypoperfusion causes tissue hypoxia and creates excess lactate due to a lack of oxygen to act as an electron acceptor in the electron transport chain and consequently slowing down the speed at which pyruvate enters into the Kreb's cycle. Serum lactate begins to rise in this early stage of shock and constriction of the vascular bed begins. Mental status, blood pressure and respiratory rate remain normal (Tintinalli, 2010).

Stage two, the compensatory stage of shock (also known as warm shock) is associated with a 15-30% blood volume loss; approximately 750-1000ml (Tintinalli, 2010). Stage two begins with compensation for decreased tissue perfusion by activating innate physiologic mechanisms such as stimulation of arterial baroreceptors, changes in respiratory rate responding to an increasing blood pH, outflow of endogenous catecholamines causing vasoconstriction, and stimulation of the renin-angiotensin system by increased secretion of antiduretic hormone from the pituitary gland (Tintinalli, 2010). Activation of these mechanisms has the common goal of delivering oxygen to vital organs such as the heart lung and brain. Physical signs of compensatory shock include tachypnea, tachycardia, narrowing pulse pressure, normal systolic blood pressure, increased diastolic blood pressure, possible reduced urine output, peripheral vasoconstriction and mild restlessness (Tintinalli, 2010). These compensatory mechanisms can allow for an up to ten percent decrease in circulating arterial blood volume without overt symptoms making compensated shock difficult to detect (Gaieski, 2015).

The third stage, progressive shock, is associated with a 30-40% blood volume loss, approximately1500-2000ml (Tintinalli, 2010) and a decrease in cardiac index to less than 2.5L/min/m2 (Gaieski, 2015). In this stage compensation begins to fail; sustained hypoperfusion leads to inappropriate cellular handling of sodium and potassium, electrolyte disturbances, worsening metabolic acidosis, increased hydrostatic pressure in the capillaries leading to fluid and protein leaking into the interstitium, histamine release and under-perfused vital organs (Tintinalli, 2010). Signs and symptoms present as a drop in systolic blood pressure to 100 mmHg or less, tachycardia, tachypnea, diaphoresis, confusion, oliguria, metabolic acidosis cool clammy skin to touch.

If left untreated the patient will progress to the fourth stage, refractory shock, which is associated with blood loss of 40% or more; approximately 2000ml (Tintinalli, 2010). This is a dire stage where end organ dysfunction and failure occurs and is often irreversible leading to cell death, brain damage and mortality. In this stage adenosine triphosphate (ATP), our metabolic cellular currency degrades to adenosine in the absence of available oxygen. Adenosine leaks into the extracellular fluid, further contributing to capillary vasodilation, and finally transforms into uric acid worsening an acidemic state. As adenosine is depleted restoration of oxygenation is futile in the absence of adenosine as a substrate to form ATP (Tintinalli, 2010). Hallmarks of this stage include extreme tachycardia, weak pulses, decrease in systolic blood pressure (70 mmHg or less) anuria and renal failure, restlessness, obtundation and coma (Tintinalli, 2010, Gaieski, 2015). Survival at this stage is very unlikely.

Monitoring: Basic and Invasive

Basic noninvasive monitoring of blood pressure, oxygen saturation, heart rate and rhythm along with constant physical assessment is immediately required for the patient in shock.

Invasive monitoring is imperative if the shock continuum progresses. Placement of an arterial line is essential to accurately and continuously monitor arterial blood pressure while offering information about valvular and ventricular function as well as serving as a portal for arterial blood sampling. A central venous catheter can be placed to monitor central venous pressure and help guide fluid resuscitation needs along with providing multiple ports for fluid and vasopressor administration. Pulmonary artery catheters are less frequently utilized today but placement can provide cardiac output and cardiac index measurements assisting with decision making in regard to pharmacological support. A urinary catheter allows for monitoring of urine output and can assist in identifying progression of end organ failure in the shock patient.

Further diagnostic tests that are useful in the identification and classification of shock are chest radiology, electrocardiogram, and echocardiogram. Results of these tests can help to rule in or rule out different types of shock depending on the findings. For instance, acute pulmonary edema upon chest x-ray and evidence of myocardial infarction on ECG can predict that the patient is experiencing cardiogenic shock independently or in concert with or as a result of another type of shock. Using multiple monitors and diagnostic tools can provide information that will help guide appropriate treatment, diagnosis and support as the resuscitation process unfolds.

Volume Replacement

Fluid resuscitation remains the first intervention recommended to support all shock patients particularly in hemorrhagic shock. At first suspicion, treatment should be initiated before a definitive diagnosis is determined (Rosenthal Saner & Chawla , 2008) Currently, there is ongoing debate in regards to best method of fluid resuscitation. Points of consideration in resuscitation strategy include choosing the type of fluid to deliver, large versus small volumes, early versus late fluid administration and the delivery of red blood cells and blood products.

Crystalloid solution remains the mainstay choice for fluid resuscitation and there are different compositions to choose from. Commonly used crystalloids are Lactated Ringers (LR) and 0.9% normal saline. Normal saline, considered an unbalanced salt solution, delivers sodium content that exceeds plasma sodium concentration thereby placing the patient at risk of developing hyperchloremic metabolic acidosis when delivered in high volumes. Because of this, balanced salt solutions are recommended over all for repletion of electrolytes that are essential to cellular physiological function of body processes. (Smorenberg, Ince & Groeneveld, 2013). Balanced solutions, such as LR, have a buffering effect and reduce the chance of developing an acidotic state related to the fluid administration and is preferred over normal saline in resuscitation (Smorenberg, Ince & Groeneveld, 2013). Evidence also suggests that LR spares stress on renal function and decreases occurrence of acute kidney injury compared to normal saline and colloid administration. Balanced solutions will not replete specific deficits of potassium, calcium and magnesium; these are best repleted with direct intravenous supplementation to foster adequate cardiac and metabolic functioning (Smorenberg, Ince & Groeneveld, 2013).

Over the years, use of colloids in fluid resuscitation has gone in and out of favor. Up to 30% of delivered crystalloid volume delivered is lost to interstitial tissue and potentially supports the benefit of colloid based fluid administration to draw fluid into the vascular space (Rasmussen, Johansson, Hojskov, Kridina, Kistorp, Thind, Nielsen, Ruhnau Pedersen, and Secher, 2014). Frequent debate continues in regard to whether concomitant delivery of colloids with crystalloid solution is beneficial to the hemorrhaging patient. Studies reveal that although delivery of colloids increases intravascular oncotic pressure they have been shown to alter the coagulation competence in bleeding patients (Rasmussen, Johansson, Hojskov, Kridina, Kistorp,

Thind, Nielsen, Ruhnau Pedersen, and Secher, 2014). A small randomized controlled trial that compared delivery of lactated ringers with the colloid solution hydroxyethyl starch (HES) to replete intraoperative blood loss revealed marked alterations of coagulation in the group receiving HES. Also, reduced development and strength of blood clots, a significant decrease in fibrinogen and platelet count and increased blood loss volume was observed in the patients receiving HES when compare to the group receiving LR (Rasmussen, Johansson, Hojskov, Kridina, Kistorp, Thind, Nielsen, Ruhnau Pedersen, and Secher, 2014). This artificial colloid was shown to reduce clot strength by reducing polymerization of fibrinogen, producing a clot that contains less fibrin and has less elasticity (Rasmussen, Johansson, Hojskov, Kridina, Kistorp, Thind, Nielsen, Ruhnau Pedersen, and Secher, 2014). Furthermore, findings also showed that the HES group required far less volume of crystalloid solution requirement and roughly twice as much volume of PRBC's to meet determined hemodynamic parameters for the study. The group receiving LR required far less PRBC transfusion but required two thirds more crystalloid volume administration to maintain the parameters and resulted in fluid excess when compared to the HES group (Rasmussen, Johansson, Hojskov, Kridina, Kistorp, Thind, Nielsen, Ruhnau Pedersen, and Secher, 2014). A larger randomized trial involving 2,857 subjects by Orbegozo et al. reveals a slightly decreased mortality rate associated with colloid based resuscitation when compared to crystalloid based resuscitation but concurs that a clear advantage to colloid based initial fluid resuscitation is still controversial (2014). A ratio of 1:3 to 1:4 colloids to crystalloid is suggested to reap the benefits of both types of fluid output (Smorenberg, Ince & Groeneveld, 2013).

Large volume resuscitation compared to smaller volume resuscitation and early compared to delayed fluid administration during hemorrhage have been studied to determine best practice

in treating volume depletion in hemorrhage (Kwan, Bunn, Chinnock & Roberts, 2014). Findings revealed small differences in mortality in each group comparison; earlier and larger fluid administration was associated with a slightly higher mortality rate but the authors did assert that the quality of the studies under review were inconclusive to determine solid guidelines for fluid resuscitation strategy. Unique factors such as the nature and location of the hemorrhage were mentioned as variables that could potentially require differences in timing and volume of fluids for the best outcomes. It was purported that larger, well concealed randomized controlled studies need to be conducted to derive solid evidence based data for the hemorrhaging patient in regard to volume and timing of fluid administration (Kwan, Bunn, Chinnock & Roberts, 2014).

Fluid resuscitation, although necessary, does come with complications. Excessive fluid replacement can cause a cyclic phenomenon for the patient experiencing shock. While fluid resuscitation does increase cardiac filling and raise blood pressure it also triggers the body to halt compensatory vasoconstriction when increased intravascular volume is detected. This leads to an increase in the rate of bleeding while adding strain to developing blood clots as vasodilation occurs. More bleeding results and hypotension and reflexive vasoconstriction once again ensues (Dutton, 2007).

Currently goal directed fluid therapy that maximizes the individuals' needs during resuscitation is favored over liberal crystalloid administration to initially treat shock. Low volume resuscitation and hypotensive resuscitation are terms used for this concept and include a target systolic blood pressure of at least 70 mmHg and a mean arterial pressure (MAP) of at least 50 mmHg compared to standard parameter goals of systolic pressure of 80-100mmHg and a MAP of 65 mmHg (Bouglé, Harrois & Duranteau, 2013). According to Smorenberg, Ince & Groeneveld, restricting fluid administration to less than 7 ml/kg/hr is associated with less

complications compared to a more liberally infused volume common to resuscitation strategies in the past (2013). Generally the lower volume concept includes rapid delivery of one to two liters of fluid (Mandel & Palevsky, 2015) then titrating fluid administration to a target heart rate, blood pressure and MAP to avoid hemodilution and dilution of clotting factors while helping to maximize the body's compensatory mechanisms in response to shock (Bouglé, Harrois & Duranteau, 2013). However, consideration of the individual patient needs and underlying pathophysiology always needs to be considered when planning fluid resuscitation.

Blood Cells, Plasma and Platelets

In hemorrhagic shock fluid replacement alone is not enough to support the patient. Intravascular volume can be replaced with fluids but red blood cells, clotting factors and platelets administration are also necessary to achieve homeostasis. Hematocrit levels between 25-30% should be maintained by early administration of packed red blood cells as needed. It is generally accepted that one unit of packed red blood cells will increase the hemoglobin level by 1 gm/dL and a 3% increase in hematocrit concentration, although 2% increase in hematocrit is probably more accurate due to studies basing the increase on 500 ml volumes of PRBC infusions and the average volume of one unit of packed red blood cells is approximately 300-350 ml. (Elzik, Dirschl & Dahners, 2006).

Past recommendations identifying parameters that indicate when to transfuse packed red blood cells followed the "10/30" rule; transfusion was initiated to keep the hemoglobin above 10gm/dL and the hematocrit at 30% (Carson & Kleinman, 2015). These parameters were rethought as transfusion related complications became better understood. Studies began to reveal that there was no significant increase in morbidity and mortality when adhering to the 10/30 rule but did show increased incidences of transfusion related complications such as transfusion

related acute lung injury (TRALI) and exposure to blood born pathogens from donated blood (Carson & Kleinman, 2015). Current literature purports that a hemoglobin level of 7-8 gm/dL is acceptable and does not require transfusion. Hemoglobin of 6 gm/dL or less is considered a critical value and indicates immediate need for replacement of red blood cells for oxygen delivery capability (Carson & Kleinman, 2015).

An exception to this threshold-based transfusion method is appreciated in the setting of acute blood loss. In hemorrhagic shock where compensatory mechanisms to maintain adequate blood pressure and tissue perfusion are failing and the patient is presenting with symptoms; tachycardia, myocardial ischemia with no response to fluid resuscitation, threshold-based transfusion method is ineffective and immediate transfusion is required (Carson & Kleinman, 2015).

Fresh frozen plasma (FFP) plasma and platelet administration along with red blood cells have been shown to increase survival in the setting of hemorrhage (Rasmussen, Johansson, Hojskov, Kridina, Kistorp, Thind, et al., 2014). FFP administration should be initiated along with delivery of PRBC's to maintain adequate circulating levels of clotting factors. The amount and timing in regard to PRBC to FFP administration ratio has been under study in the literature and recent findings are controversial (Bouglé, Harrois & Duranteau, 2013). A PRBC/FFP ratio 1:3 or 1:4 has been acceptable but studies assessing alterations in coagulation have instigated the more current recommendations suggesting a 1:2 ratio (Bouglé, Harrois & Duranteau, 2013). Current military studies focused on acute traumatic blood loss reveal that a 1:1:1 ratio, PRBC's to FFP to platelets, have shown improved outcomes in emergency resuscitation efforts but Bouglé, Harrois & Duranteau report that studies reveal early death from hemorrhagic shock is associated with

higher PRBC to FFP ratios (2013). Platelet administration should be initiated to maintain a platelet count of greater than 50,000.

Diagnostic Tools

Evaluation of laboratory tests can assist in the identification and presence of shock and help determine the level of organ failure involved. Integral laboratory tests that are extremely useful in diagnosing and treating shock include serum lactate, complete blood count, basic and comprehensive metabolic panel, and coagulation profile and arterial blood gas analysis.

An increased serum lactate level can offer indirect information on how well body tissues are being perfused. Serum lactate level is a direct reflection of anaerobic metabolism occurring in the body system and reflects low oxygen delivering capacity and a hypo-perfused state. Lactate levels rise when anaerobic respiration at a cellular level is being utilized as a compensatory attempt to oxygenate tissues to maintain organ function. Normal compensatory mechanisms can maintain blood pressure initially while hypoxia at the tissue level has already begun; this is otherwise known as “cryptic shock” (Gaieski, 2015). Monitoring lactate level is a valuable tool allowing for early intervention before symptoms and the shock cascade progress. Lactate levels are considered normal at 2mmol/L; levels greater than 4.0 mmol/L are associated with a 30-40% increase in mortality (Rosenthal Saner &Chawla, 2008).

Hematological studies are useful in the detection, diagnosis and treatment of hemorrhagic shock and allow the practitioner to assess hemoglobin, hematocrit, platelet count, white blood cell count and coagulation. Trending hemoglobin and hematocrit levels provides information during resuscitation efforts. Having knowledge of expected increase in these blood values when transfusions are being administered can help the provider discern the possibility of continuing occult blood loss.

Coagulation studies such prothrombin time, international normalized ratio, activated partial thromboplastin time, fibrin and fibrinogen levels and d-dimer can provide information about the coagulopathic state of the patient in shock. Coagulopathy is associated with longer hospital stays, longer time on mechanical ventilation and higher incidence of multi-organ failure and mortality. The 'vicious triad' of acidosis, hypothermia and hemodilution that occurs in shock initiates coagulopathy. (Cohen and Kutcher, 2015). Acidosis has been determined to cause clotting dysfunction in experimental models at a pH less than 7.2 and physical exposure in the operating room, fluid administration, and the effects of general anesthesia all contribute to hypothermia and can worsen coagulopathy. The effect of hypothermia on clotting includes platelet dysfunction and impaired enzymatic function (Cohen and Kutcher, 2015). Providers should undertake specific measures to correct hypothermia including controlling physical exposure, administration of warmed fluids, and passive rewarming with blankets and forced-air devices. In hemorrhage, rapid identification and control of bleeding is vital to preserve normal temperature. Continuous temperature monitoring is essential to ensure that mild hypothermia does not worsen (Cohen and Kutcher, 2015). Alterations in clotting that are induced by large volumes of fluid or unbalanced blood component administration during the management of shock are known as resuscitation-associated coagulopathy (Cohen and Kutcher, 2015). Historically, resuscitation placed focus on treatment of hypotension and acidosis with aggressive crystalloid resuscitation followed by packed red blood cells. Studies revealed that resuscitation with crystalloid, colloid, and packed red blood cells leads to dilution of plasma clotting proteins and a current recommendation for those receiving larger volumes of blood products and fluids should receive packed red blood cells, fresh frozen plasma and platelets to avoid deleterious effects associated with coagulopathy (Cohen and Kutcher, 2015).

Obtaining basic and comprehensive metabolic panels offer a wide variety of information in the shock state. These studies are valuable when evaluating the extent of end organ damage related to shock and can help to stage shock in the patient. Testing of basic electrolytes such as potassium, calcium, chloride, carbon dioxide, magnesium and phosphorus provides a snapshot of fluid and electrolyte balance of the patient. In the later stages of shock hyponatremia, hyperkalemia and hypercalcemia can present as a result of the altered membrane function, cellular edema and cell death (Tintinalli, 2010). Excessive fluid administration alters serum sodium levels and monitoring and correction is necessary. Receiving blood transfusions in large volumes can instigate elevated levels of potassium and calcium associated with preservatives and the aging process of red blood cells in banked blood. Blood urea nitrogen and creatinine levels can offer a reflection of kidney function and/or extent of kidney failure. A comprehensive panel that includes assessment of liver enzyme levels reflects hypoperfusion affecting hepatic function and reflects end organ damage. Metabolic derangements are essential to support or correct regardless of whether its etiology is related to the state of shock or occurring as a result of interventions and treatments. The patient is at risk for life threatening consequences of altered electrolyte balance such as cerebral edema, myocardial dysfunction, pulmonary edema and interruption of essential cellular metabolic functions.

Arterial blood gas analysis is an integral laboratory tool, revealing the degree of metabolic acidosis that presents in shock states; acidosis increases in severity as shock progresses. Blood gas analysis guides the anesthetist to determine need for intubation and mechanical ventilation and mitigate and treat progressing acidosis with appropriate ventilator settings. Obtainment of cardiac enzymes is a fast way to determine if cardiac ischemia and tissue damage is has occurred in the setting of hypoperfusion.

Vasopressor Support

In the setting of shock providing volume is crucial but control of systemic vasoconstriction comes in close second. In situations where volume repletion with fluids and blood products and homeostatic mechanism does not stabilize hemodynamic and circulatory status vasopressors must be added to the supportive regime (Smorenberg, Ince & Groeneveld, 2013). Various vasoactive agents are available and can be tailored to the type of support needed in the shock state.

Epinephrine is the mainstay emergency vasopressor. It is the first line catecholamine in cardiopulmonary and anaphylactic shock and serves as second line therapy when used as a vasopressor and positive inotropic agent. Effects are elicited on both alpha and beta-adrenergic receptors and increased heart rate and enhanced cardiac output result.

Norepinephrine, an endogenous catecholamine with both alpha and beta adrenergic properties, elicits a vasoconstrictive effect on both arterial and venous blood vessels resulting in an increased mean arterial pressure, preload, and venous return. Meanwhile norepinephrine, unlike epinephrine, helps to decrease heart rate and stroke volume in the shock patient. Norepinephrine is indicated for use in distributive or vasodilatory shock (Rosenthal, Saner & Chawla , 2008).

Phenylephrine is a selective alpha-adrenergic agonist and is useful in setting of adequate cardiac output to increase mean arterial pressure, systemic vascular resistance and central venous pressure. As seen in hemorrhage, phenylephrine can be utilized for hypotension associated with vasodilation for restoration of blood pressure along with a decrease in cardiac output. (Rosenthal, Saner & Chawla , 2008).

Dopamine is both an alpha and beta adrenergic agonist that stimulates alpha, beta and dopaminergic receptors and can be utilized in varying strengths to elicit desired responses. Low dose therapy targets dopamine receptors and has had a history of being useful in enhancing renal perfusion although current studies currently reveal that there is no appreciable increase in renal perfusion related to low dose dopamine therapy. At moderate dosage dopamine has an inotropic effect via stimulation of beta-receptors and high doses elicit alpha-1-receptor stimulation and results in systemic vasoconstriction. Dopamine is helpful when bradycardia and vasodilatory shock is present due to its inotropic effects in a low cardiac output state causing an increased heart rate and vasoconstriction. Caution is warranted as dopamine in high doses increased metabolic consumption of oxygen and can predispose the patient to cardiac arrhythmias and myocardial infarction (Rosenthal, Saner & Chawla, 2008).

Dobutamine is a sympathomimietic agent that primarily stimulates beta 2 receptors making it useful in the setting of cardiogenic shock with decreased cardiac output and increased afterload due to its inotropic effect and ability to decrease systemic and pulmonary vascular constriction. Dobutamine can be used in conjunction with norepinephrine to treat septic shock with myocardial dysfunction present (Rosenthal, Saner & Chawla, 2008).

There are various pharmacological agents that are non-adrenergic in action and can be used as adjuvant therapy for the shock patient. Calcium channel sensitizers are a class of medication that are inotropic with a vasodilatory effect. They are indicated for use in severe low output states and in heart failure. Levosimedan and Pimobendan are two agents in this class. Prostaglandin III inhibitors, such as milrinone and amrinone, mobilize intracellular calcium resulting in increased vasodilation and positive inotropic effect. These agents are known to improve cardiac output in cardiogenic shock whether it be the primary shock state or a secondary

state caused by hypovolemia or distributive shock. Calcium overload, ventricular arrhythmias and cell death is a possibility with use of these agents (Rosenthal, Saner & Chawla, 2008).

Vasopressin, otherwise know as antidiuretic hormone (ADH), is a naturally occurring stress hormone that acts on the kidneys in the collecting ducts to retain water and increases peripheral vascular resistance thereby increasing blood pressure. The mechanism of action involves the renin-angiotensin-aldosterone system to elicit its effects. Vasopressin delivery is desirable especially in the setting where adrenergic agonists are failing to raise blood pressure. Vasopressin is useful in the setting of hypovolemic shock and septic shock when naturally occurring ADH is depleted. With sepsis, vasopressin can be combined with norepinephrine to support hemodynamic status (Rosenthal, Saner & Chawla, 2008).

Continuum of Care

In shock early resuscitation attempts demand prioritizing interventions. Initiating an advanced life support assessment should occur first and foremost when suspecting or determining a shock state. Airway, oxygenation and circulation status are of vital importance. Supplemental oxygen should be immediately initiated and the airway should be secured and ventilation controlled if any compromise to maintaining effective spontaneous ventilation is present or a decreasing level of consciousness is putting the patient at risk of failing to maintain an effective airway.

Fluid resuscitation should be initiated at the first suspicion of shock. Crystalloid resuscitation due to its ability to rapidly expand plasma volume and reverse hypotension related to physiologic compensatory changes continues to be the first line treatment in an emergent hemorrhage situation (Rasmussen, Johansson, Hojskov, Kridina, Kistorp, Thind, et al., 2014). Fluid administration should be titrated to achieve hemodynamic goals and avoid excessive

delivery. With the airway secure and initial volume bolus delivered the patient's circulatory status should be continually monitored and supported with crystalloid and/or colloid infusion and addition of vasopressors, if required, to achieve hemodynamic goals. Concurrently, blood samples should be obtained for laboratory testing; initially a serum lactate, hemoglobin and hematocrit, BMP, platelet count and ABG should be drawn. Blood and FFP infusions should be readied and administered if indicated by amount of PRBC's delivered, obvious acute blood loss or suspected by results of hematological studies. An arterial line and central line should be placed if not already present to guide resuscitation efforts and offer arterial blood sampling. Additional labs such as coagulation studies, ionized calcium, magnesium, and cardiac enzymes can be drawn for further data. With suspicion for hemorrhagic shock, cessation of bleeding is the number one priority to reverse the shock state and plans for return to the operating room for exploration should be discussed with surgical team immediately. Treatment and support for shock is a dynamic process requiring complex thinking and teamwork.

Clearly, there is a lot of controversy regarding the optimal resuscitation strategy to treat shock and but the overriding goals remain the same: delivery of oxygen to tissues, avoiding hypoxia, mitigating inflammation and avoiding organ dysfunction. There are many methods and ways to achieve this safely as an anesthesia provider with expert understanding of the shock continuum, prompt intervention, comprehensive monitoring and use of laboratory and diagnostic tools to understand the needs of the patient and guide the resuscitation strategy. Development of an algorithm of care to treat shock in the form of a cognitive visual aid can help ensure all critical components of care are performed and help to reduce adverse consequences associated with shock.

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